Corvallis Watershed Stream Temperature Monitoring
Summer 2011

April 18, 2012

Introduction

The City of Corvallis and the Siuslaw National Forest have cooperatively monitored the stream temperatures in the Rock Creek Watershed during the summers of 2005, 2006, 2010 and 2011. The objectives of the stream monitoring are:

- to characterize the stream temperatures throughout the watershed.
- to determine the effects of restoration efforts, such as plantation thinning, riparian planting and wood placement.
- to determine if it is possible to measure effects of the reservoir on downstream temperatures, if any.

In addition to monitoring stream temperatures, air temperatures at three sites were also monitored to compare air and water temperatures, and to see how warm the summers were.

Figure 1 shows the location of the sites.

The results are summarized in Table 1, which shows the 7-day average maximum temperatures for the sites.

Restoration Efforts in the Corvallis (Rock Creek) Watershed

The City of Corvallis, the Siuslaw National Forest, the Marys River Watershed Council and the Marys Peak Stewardship Group have worked together to improve habitat and water quality in the Rock Creek watershed. Previous efforts include the replacement of four undersized culverts with Aquatic Organism Passage culverts, adding fish ladders to the South Fork Rock Creek and Griffith Creek water intake weirs, the addition of large wood complexes to the mainstem of Rock Creek, and riparian planting along 3000 feet of the mainstem of Rock Creek. The Rock Creek water treatment plant employees have noted that the replaced culverts appear to have no negative effects from the January 19, 2012 flood event, and more bedload gravels have been captured behind the large wood complexes. Some of the logs have moved downstream.

The projects that will potentially have the most direct effect on stream temperatures over the long term are the large wood placement and riparian planting. As gravels are deposited behind the wood complexes, more of the stream flow will be subsurface through the gravels instead of flowing on top of bedrock. The subsurface flow aids in keeping water cool.

Discussion

Watershed Characterization

The stream temperature monitoring in the Corvallis (Rock Creek) Watershed since 2005 has shown that most of the sites meet the state water quality standard of 64F most of the time. See Table 1

Factors that can influence water temperature include stream shading, the amount of substrate in the stream channel, the aspect of the stream channel, the width of the stream and air temperatures.

Water temperatures increase downstream with increasing drainage area and stream width. The Corvallis (Rock Creek) Watershed is no exception. The correlation between drainage area and stream temperature is good, as shown by the high R^2 values for the linear regression lines (Figure 2). Figure 2 also illustrates the point that stream temperatures vary systematically from year to year, depending on air temperatures. Data (Figure 3) from the Green River watershed, a tributary to Five Rivers in the Alsea River basin is included for comparison. It also shows the high correlation between increasing drainage area and increasing water temperatures. The flows in the Green River watershed are unregulated.

Summer air temperatures are a large influence on water temperatures. Figure 4 shows the air temperature as compared to four of the water temperature sites. While the diurnal fluctuation is greater for the air temperatures, the water temperatures closely follow the high and low daily temperatures. This influence of air temperatures can also be documented from year to year. The Cannibal Mountain Remote Automatic Weather Station (RAWS) in the Coast Range has 37 years of data. The 20th warmest summer in this record was 2010; the 7th warmest summer was 2011. The difference between the two summer air temperatures can be seen in the water temperatures (Table 1). In 2011, all the sites were slightly warmer than in 2010, with the exception of upper Griffith Creek (0.7 degrees F cooler in 2011) and the mainstem of Rock Creek just below the confluence (0.9 degrees F cooler in 2011). Therefore, it can be expected that warm summers will producer warmer water temperatures, and vice versa. Sites that are within a degree or so of the 64 degree standard may be under the standard one year, and over it the next. The time of summer when the warmer stream temperatures occur is also weather-dependent. Figure 16 shows how air temperatures can vary from year to year. The warmer peaks came later in the summer in 2011 as compared to 2010.

Watershed Restoration Project Monitoring

Large wood was added to the mainstem of Rock Creek in 2008. One of the large wood complexes was placed just downstream of the North and South Forks of Rock Creek confluence, and upstream of the water temperature monitoring site that is in the mainstem below the confluence. Over time, the large wood complexes are expected to capture streambed substrate and create deeper pools. These changes in stream substrate

and habitat are expected to influence stream temperature. At this time, there is not a long enough monitoring time frame to determine if the wood placement is having an effect, and to distinquish the effects of the wood placement from the random yearly variation in temperature.

Effects of the Rock Creek reservoir on downstream temperatures

Long-term monitoring will be needed to determine whether or not the reservoir is having an effect on downstream water temperatures. At this point, the results are not conclusive.

The only evidence that the reservoir may have an effect is the following: In 2005, 2010, and 2011, there is a bigger difference in temperatures between the South Fork Rock Creek site just above the intake and the mainstem Rock Creek site just below the confluence during the early part of the summer as compared to the later part of the summer. (Figures 6-12). The range of differences is between 2 to 4 degrees. However, there are other factors that may explain the slightly warmer temperature difference downstream in the earlier summer.

1. During the warmest part of the summer in late August, the spillway is dry, and the reservoir is not contributing any water to the downstream channel. During most of the summer, the water over the spillway is a trickle, and is just enough to keep the moss in the spillway wet. The pool at the bottom of the spillway is stagnant, and the temperatures are close to air temperatures in this pool. However, it does not contribute enough flow to influence stream temperatures compared to the flow in the South Fork and mainstem.

   For comparison, water temperatures were bracketed in the Drift Creek Wilderness (Alsea River basin) in 2009. Temperatures were measured upstream and downstream of Boulder Creek, and at the mouth of Boulder Creek within the wilderness. Although some timber harvest has taken place in the Boulder Creek subwatershed in past decades, the subwatershed is well vegetated and the stream is shaded. Temperatures for Drift Creek upstream and downstream of Boulder Creek are 72.3 and 72.4 F. The mouth of Boulder Creek is 59.7F. The Boulder Creek drainage area is 10% of the Drift Creek watershed drainage area. Assuming it contributes 10% of the flow to Drift Creek, even a 10% contribution was not enough to change the temperature of Drift Creek more than a tenth of a degree. The trickle coming down the spillway would be a far less contribution to the mainstem flow in Rock Creek.

2. Stream temperatures increase downstream with increasing stream width and drainage area. The site downstream of the confluence is not far off the trend line (Figure 2).

3. In 2005, 2006, and 2010, the warmest air temperatures occurred in July, which would raise water temperatures. In general, the warmer air temperatures seem to have more of an effect on the larger streams where groundwater is less of an influence overall. In 2011, the warmest temperatures occurred in late August and early September.

Interestingly, the stream temperatures that were recorded downstream of the confluence and the dam were cooler than the south fork just above the confluence, beginning on August 10 and continuing through early September in 2011. The mainstem site below the confluence began cooling down relative to the South Fork in the latter part of July. The reservoir level dropped below the inlet of the spillway on or before August 15. Temperature differences between the South Fork site just above the confluence and the mainstem site just below the confluence ranged from 3.6F on July 24, with the mainstem being the warmer site, to 1.9F on August 26, with the South Fork being the warmer site. While the mainstem site didn't increase in temperature through the summer, the South Fork did increase into September at both temperature sites.

Why would the mainstem be cooler than the South Fork site just above the confluence during the latter part of the summer in 2011?

Possible hypostheses might include the following:

1. The large wood complex between the confluence and the monitoring site has captured sufficient substrate to cool the water. This seems unlikely, as the distance between the confluence and wood complex is short.
2. Groundwater may play a bigger role at this site than just above the confluence in the South Fork Rock Creek.
3. The mainstem flows southeast, while the South Fork flows northeast. The center of the mainstem channel aligns with the sun's angle in the morning; the center of the South Fork's channel aligns with the sun's angle in the afternoon. The aspect of the stream channel may influence how much shading the stream channel receives during the warm part of the day.
4. Inaccuracies in the probe measurements? Only two sites recorded cooler temperatures in 2011 than in 2010; the Rock Creek mainstem below the confluence and upper Griffith Creek. No site changes have been noted at the Griffith Creek site.

It has been suggested that the mainstem stream temperatures might be cooler if the lower valve in the reservoir was partially opened during the summer. This suggestion assumes that the water at the bottom of the reservoir would contribute cool water downstream. When the reservoir was emptied in late September, 2005 to repair the valve, this suggested experiment was a by-product of that drawdown. The drain was opened on September 23, 2005. Reservoir surface elevation levels were measured every day between 10 am and 1 pm. On September 23, the reservoir was at 52.0 feet, 6 feet below the maximum water surface elevation of the reservoir. Within 3 hours, the stream temperature just below the confluence of the North Fork and South Fork Rock Creek in the mainstem had **risen** 8.24 degrees F. After this rapid increase, the stream

temperature at that site then leveled off to just below 60 degrees F for the rest of the time that the reservoir was draining. The reservoir was empty on September 30, 2005, except for the streambed flow through the bottom of the reservoir. Once the reservoir was empty, the temperature graph for the site below the confluence was very close to the site on the South Fork, and showed the expected diurnal fluctuation. The drain valve was closed on December 1, 2005 and the reservoir was filled to capacity by December 9, 2005. The rate of drop during the week of drawdown in September was, on average, 0.24 feet per hour. See Figure 18 (page 26) and Table 3 (page 27).

More long-term monitoring will be needed to determine the effects of management activities, including watershed restoration projects, on water temperature trends.

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April 18, 2012

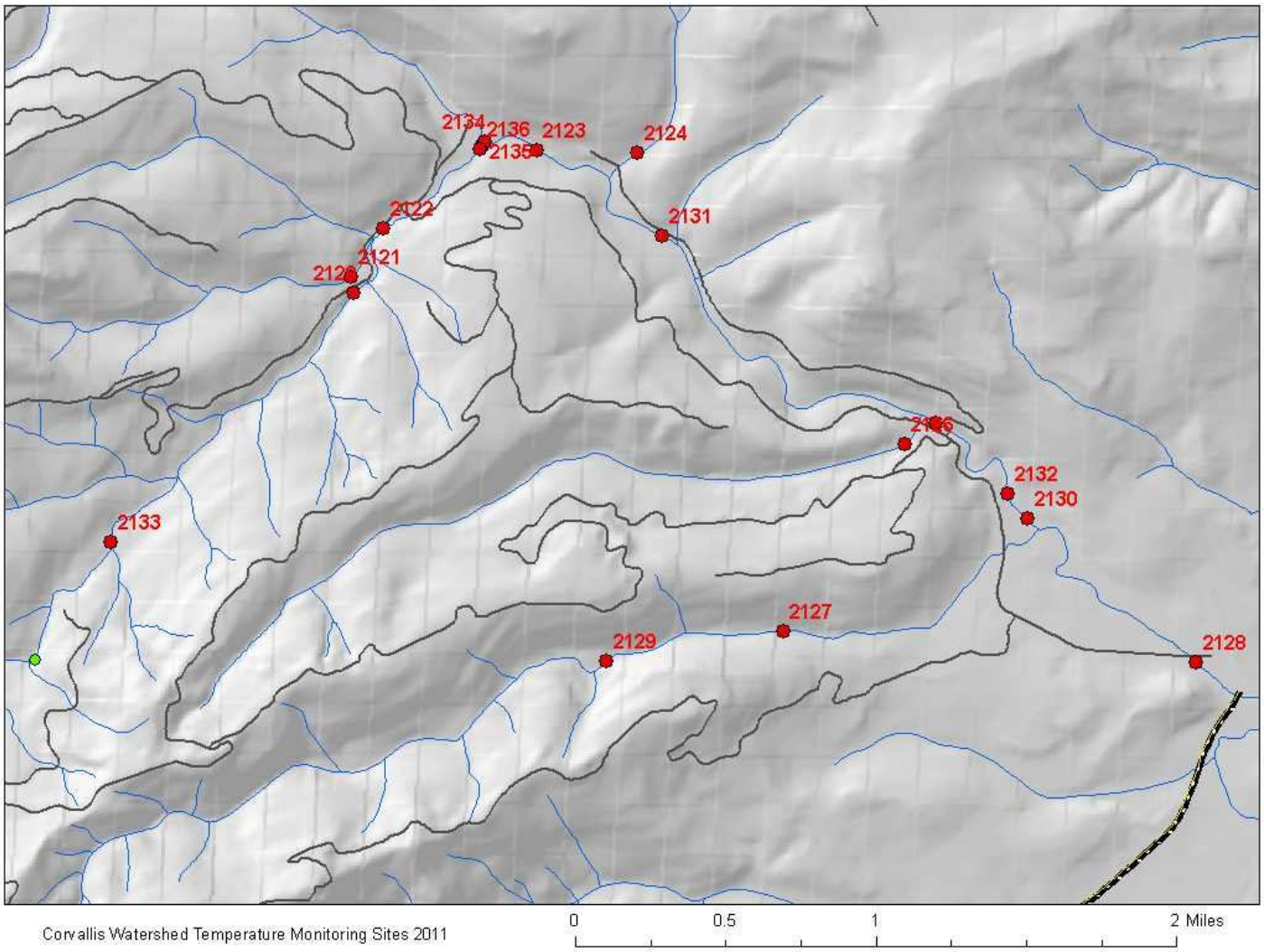

Figure 1. Location of temperature monitoring sites with identifying numbers in the Rock Creek watershed during the summer of 2011.

Table 1. Summary of stream temperature data.

STREAM	LOCATION	STATION number	1978 7-day ave max	1980 7-day ave max	2005_7-day ave max	2006_7-day ave max	2010 7-day ave max	2011 7-day ave max	Objective
S FK Rock Creek	upstream from Connection Creek	2120			60.8		59.2	**60.1**	watershed characterization, bracketting Connection Cr
Tributary to S FK Connection Creek	Tributary is upstream from and next to Connection Creek	2121			61.2		58.8	**59.6**	watershed characterization
S FK Rock Creek	Above weir tied to trash rack	2122			60.9		58.8	**60.1**	watershed characterization
S FK Rock Creek AIR TEMP		2122					79.06	79.1	comparing air temp
Rock Cr mainstem Water Temp	downstream from confluence of N Fk and S FK Rock Creek	2123			66.4	67.5	61.9	**61.0**	monitor effects of reservoir
Rock Cr mainstem AIR TEMP	downstream from confluence of N Fk and S FK Rock Creek	2123			81	92			compare air temp
Stilson Creek	upstream from rd 111	2124			62.5		60.2	**61.4**	watershed characterization
Rock Creek mainstem	upstream from rd 111 bridge	2125			67.8		63.2	64.4	watershed characterization, monitor changes in riparian area and stream substrate restoration
Rock Creek mainstem AIR TEMP	upstream from rd 111 bridge	2125					81.3		

Middle Fork Rock Creek	upstream from rd 3405	2126			62.3		59.6	**61.4**	watershed characterization
Griffith Creek	upstream from weir	2127			60.9		59.3	**60.2**	watershed characterization
Rock Creek	below bridge near entrance gate	2128					64.2	**65.6**	watershed characterization
Griffith Creek	below thinning unit approx 1 mi from intake	2129					61.5	**60.2**	monitor thinning effects
Rock Cr mainstem	at waterline crossing upstream of Griffith Cr	2130					63.9	**65.2**	bracket outflow
Rock Cr mainstem	0.08 miles upstream from Trib "b"	2131					61.9	**63.1**	watershed characterization
Rock Cr mainstem	at City/pvt boundary above outflow in log complex	2132					63.3	**64.5**	bracket outflow
S Fk Rock Creek	below thinning stand	2133	63.5	65.943			58.3	**59.3**	monitor thinning effects
S Fk Rock Creek	above thinning stand (clearcut in 1979?)		60.543	58.126					
N Fk Rock Creek	In stagnant pool below dam spillway just above confluence with S Fork							77.04	Bracket reservoir
S Fork Rock Creek	above dam outlet and confluence with N Fork Rock Cr	2136						62.12	Bracket reservoir
Ranking of summer air temps, based on 37 years of dta from Cannibal RAWS			15, middle	30, lower third	10, upper third	1, hottest	20, middle	7, upper third	
STREAM	**LOCATION**	**STATION number**	**1978 7-day ave max**	**1980 7-day ave max**	**2005_7-day ave max**	**2006_7-day ave max**	**2010 7-day ave max**	**2011 7-day ave max**	**Objective**

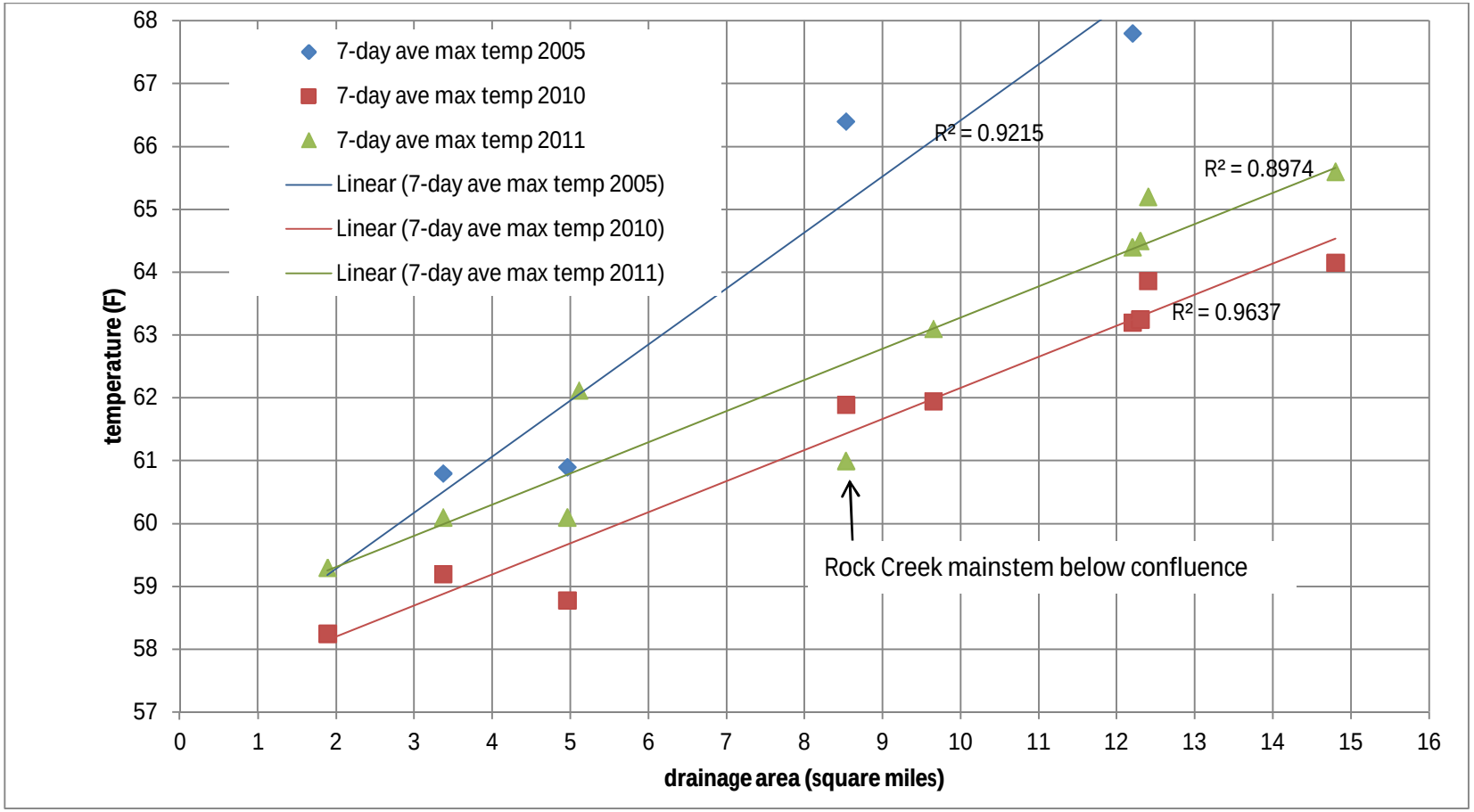

Figure 2. Graph comparing stream temperature to drainage area at that point. For all three years of data, water temperatures become warmer downstream. The trend lines are the linear regression curve fit to the data, with the R squared value. The Rock Creek mainstem site below the confluence is the one site that was cooler in 2011 than in 2010.

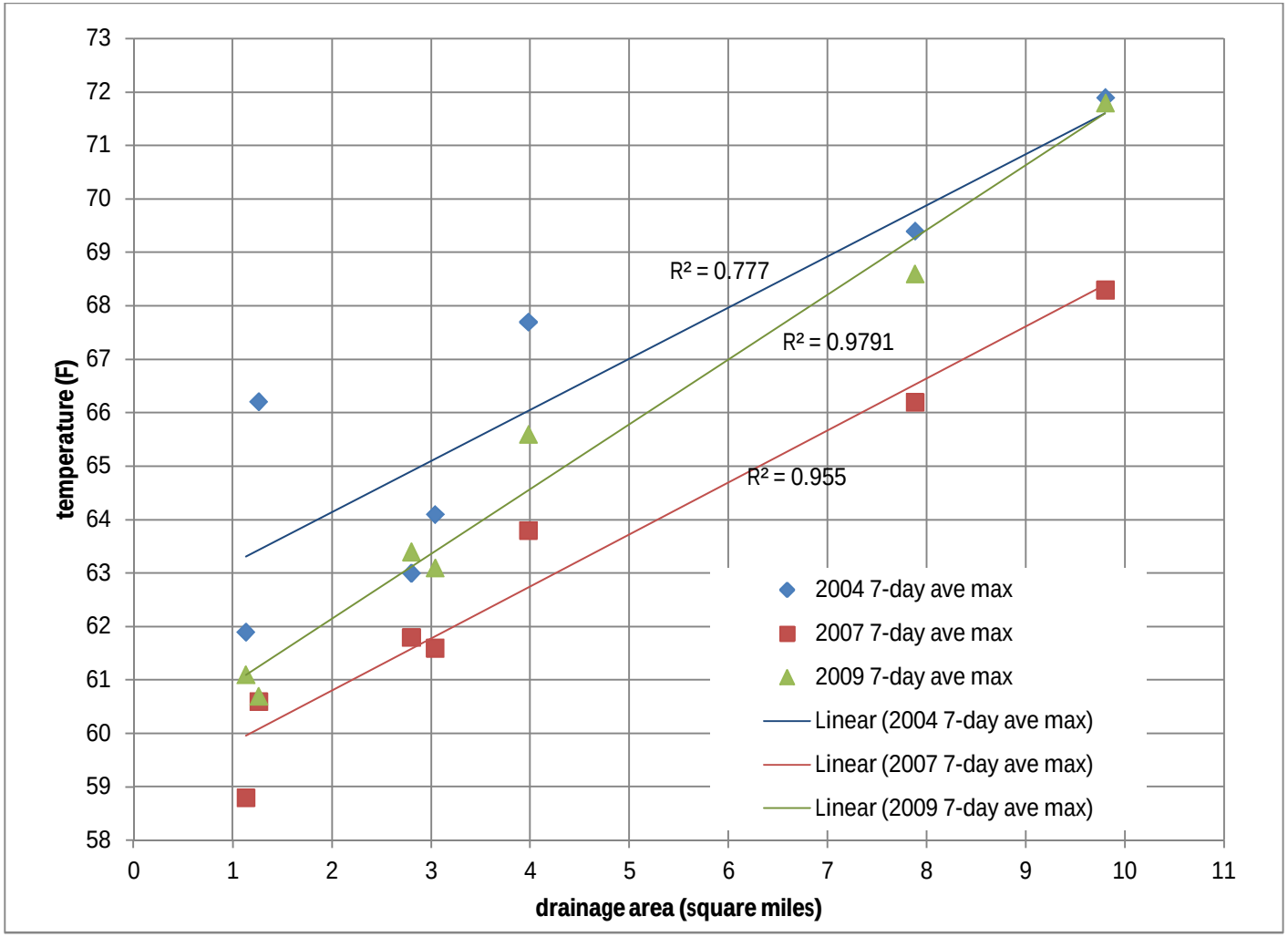

Figure 3. Graph showing relationship of drainage area to stream temperature in the Green River watershed, tributary to Five Rivers in the Alsea River basin. This watershed has unregulated flows. The trend of warming stream temperatures in a downstream direction is illustrated. Note the R squared values are similar in both watersheds.

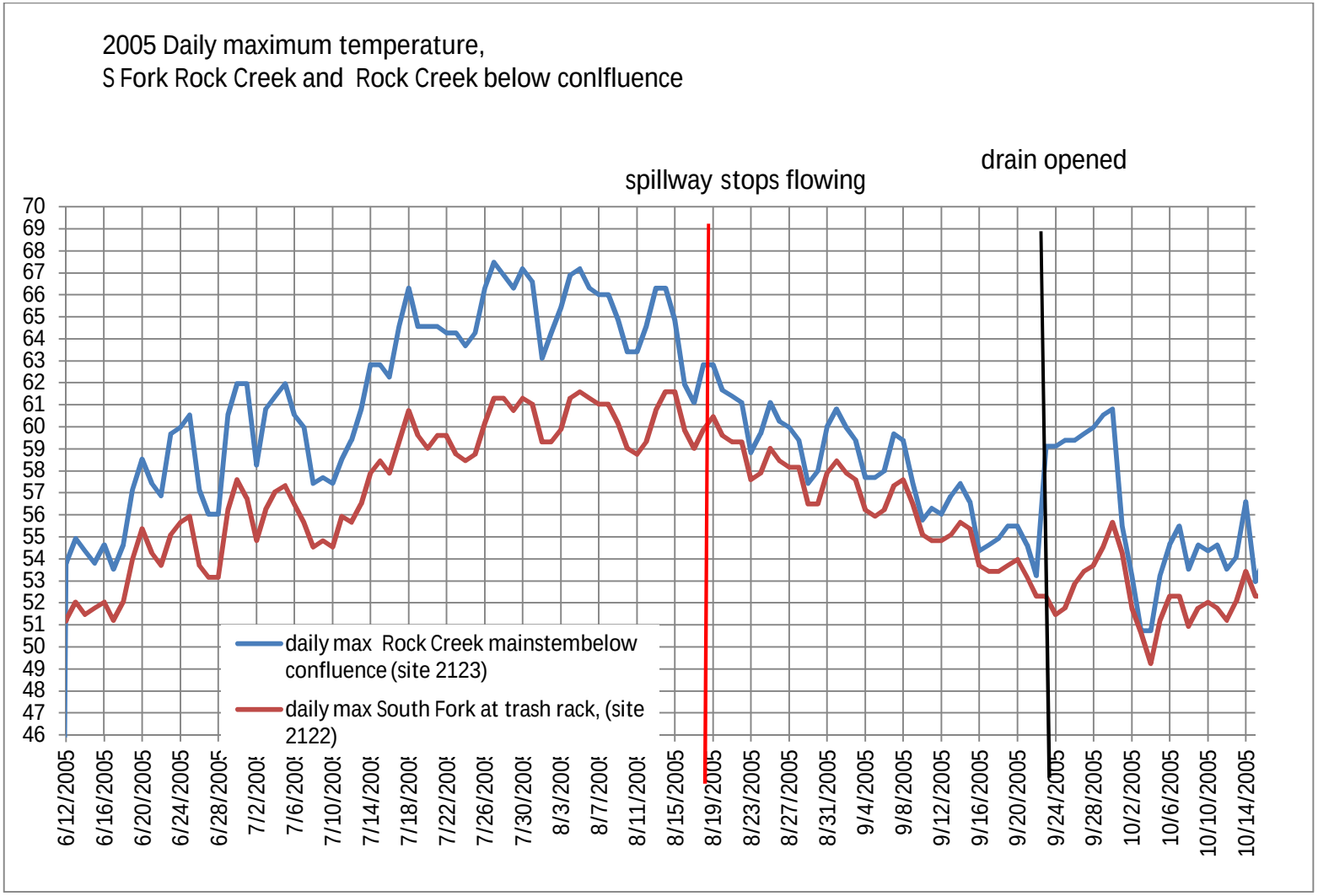

Figure 4. Comparison of stream temperatures above the intake on South Fork Rock Creek with the Rock Creek mainstem below the conlfuence in 2005. The spillway stopped flowing completely on August 18, 2005. The reservoir was drained in late September for repairs. Late September also had higher than normal air temperatures.

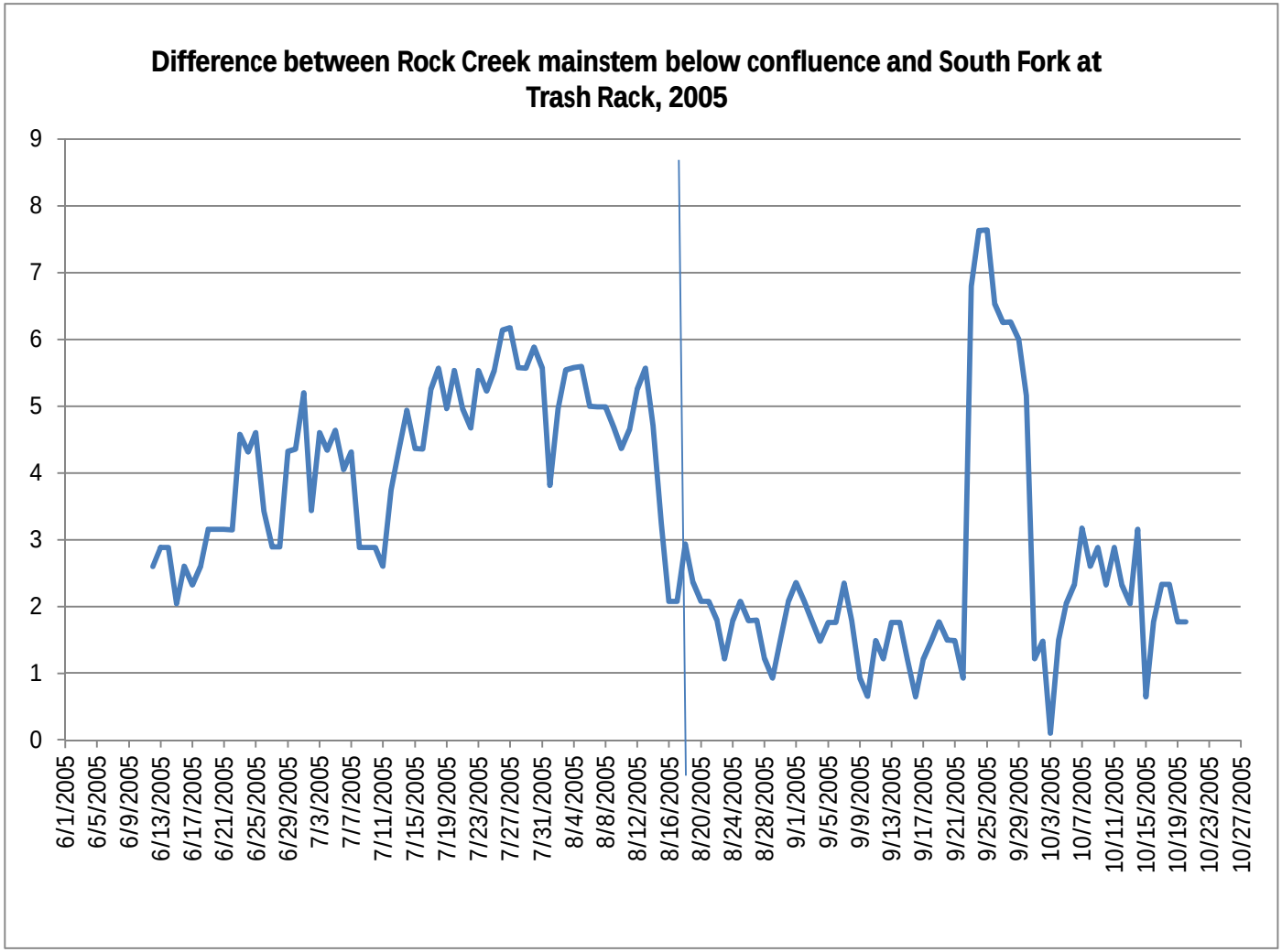

Figure 5. Difference in maximum daily temperatures between Rock Creek mainstem below the confluence and the South Fork above the intake in 2005. The spike in temperature differences in late September took place when draining the reservoir coincided with higher air temperatures.

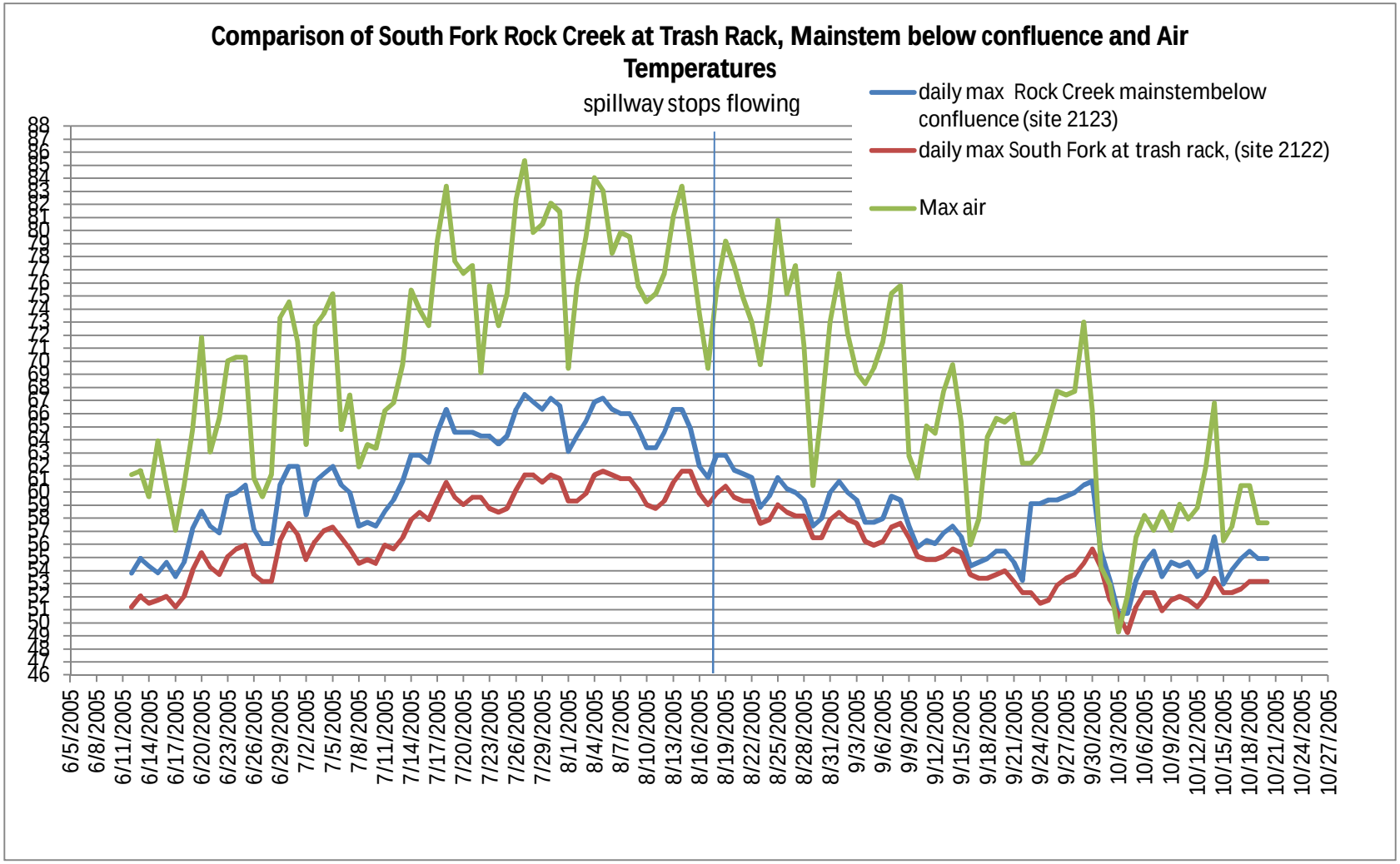

Figure 6. Comparison of South Fork Rock Creek above the intake with the mainstem, with maximum daily air temperatures added, 2005. The highest air temperatures occurred prior to the date when the spillway stopped trickling.

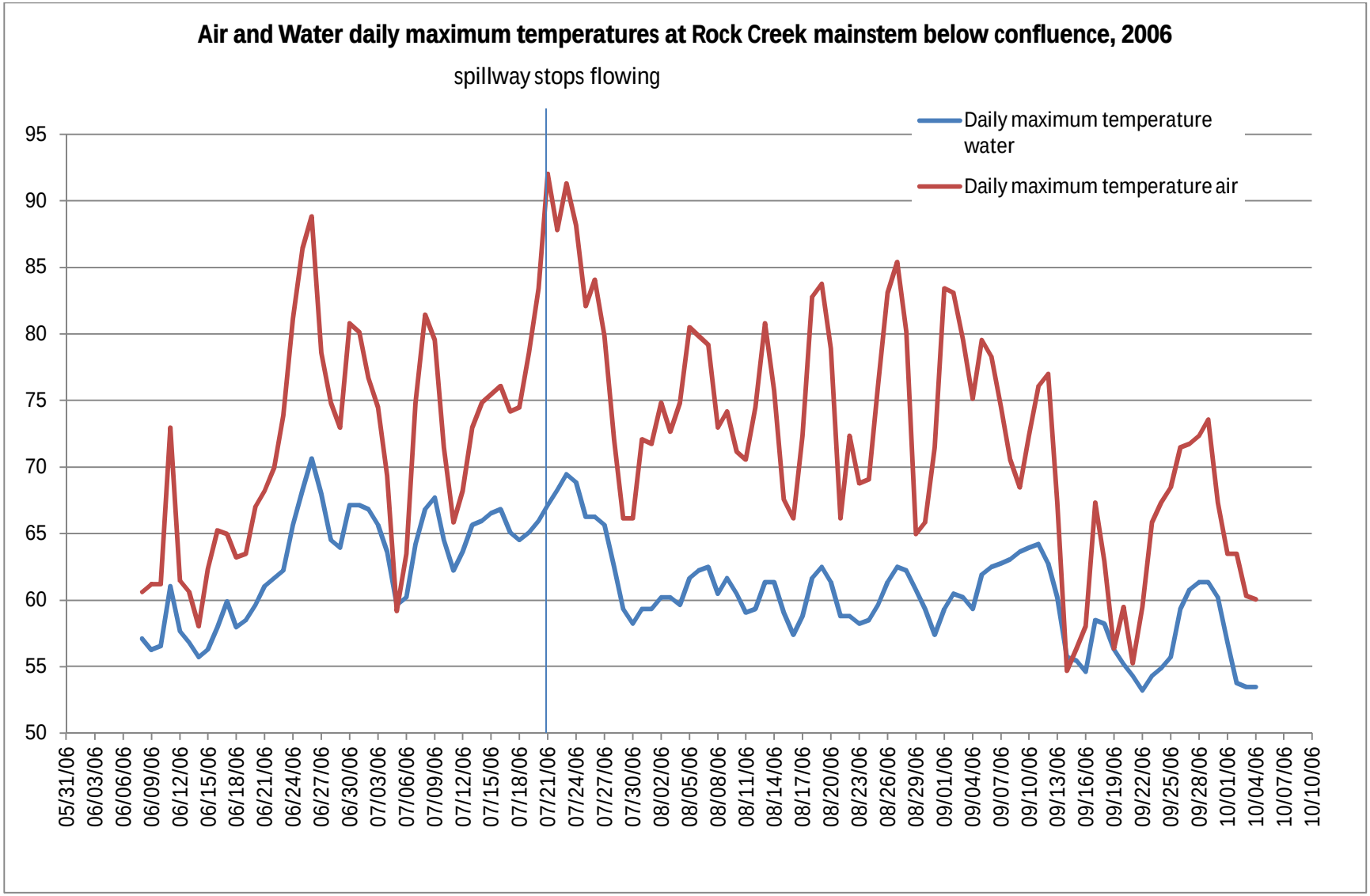

Figure 7. The Rock Creek mainstem site below the confluence was the only site monitored in the Corvallis (Rock Creek) Waterhsed in 2006. The highest air temperature coincides with the time period when the spillway stopped trickling.

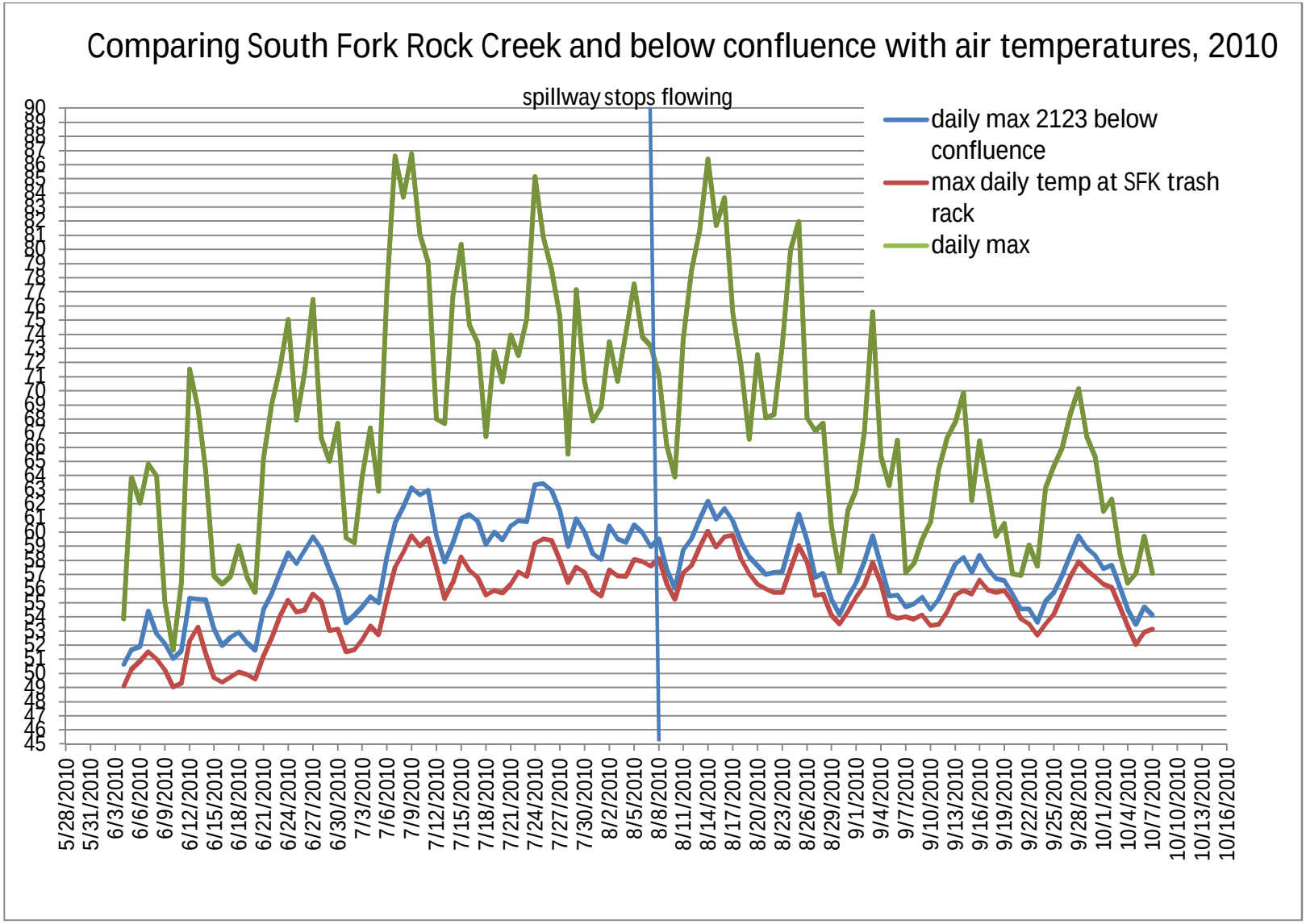

Figure 8. Comparison of South Fork Rock Creek above the intake with the mainstem, with maximum daily air temperatures added, 2010.

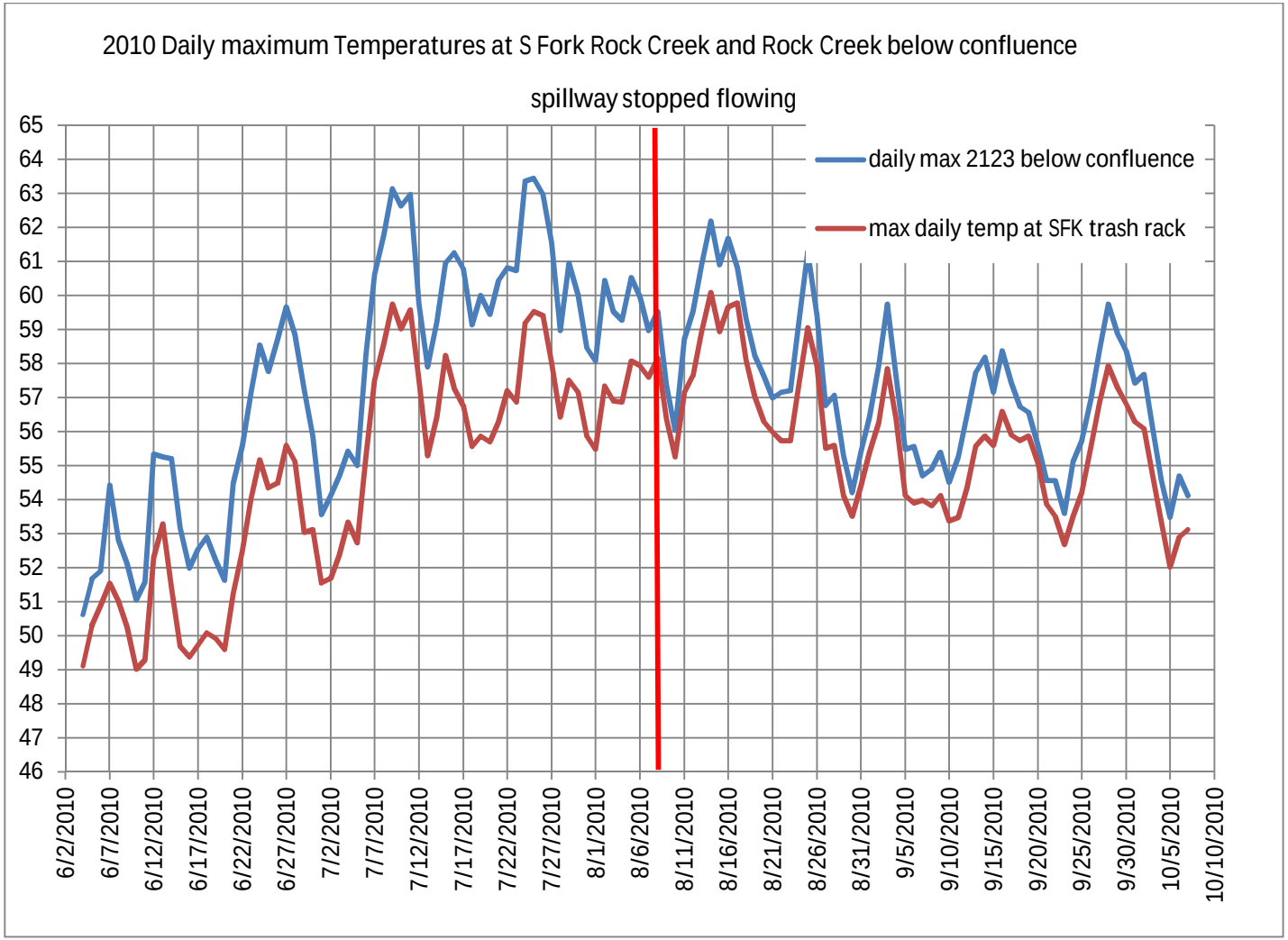

Figure 9. Comparison of maximum daily stream temperatures at the South Fork Rock Creek above the intake and the mainstem below the confluence in 2010.

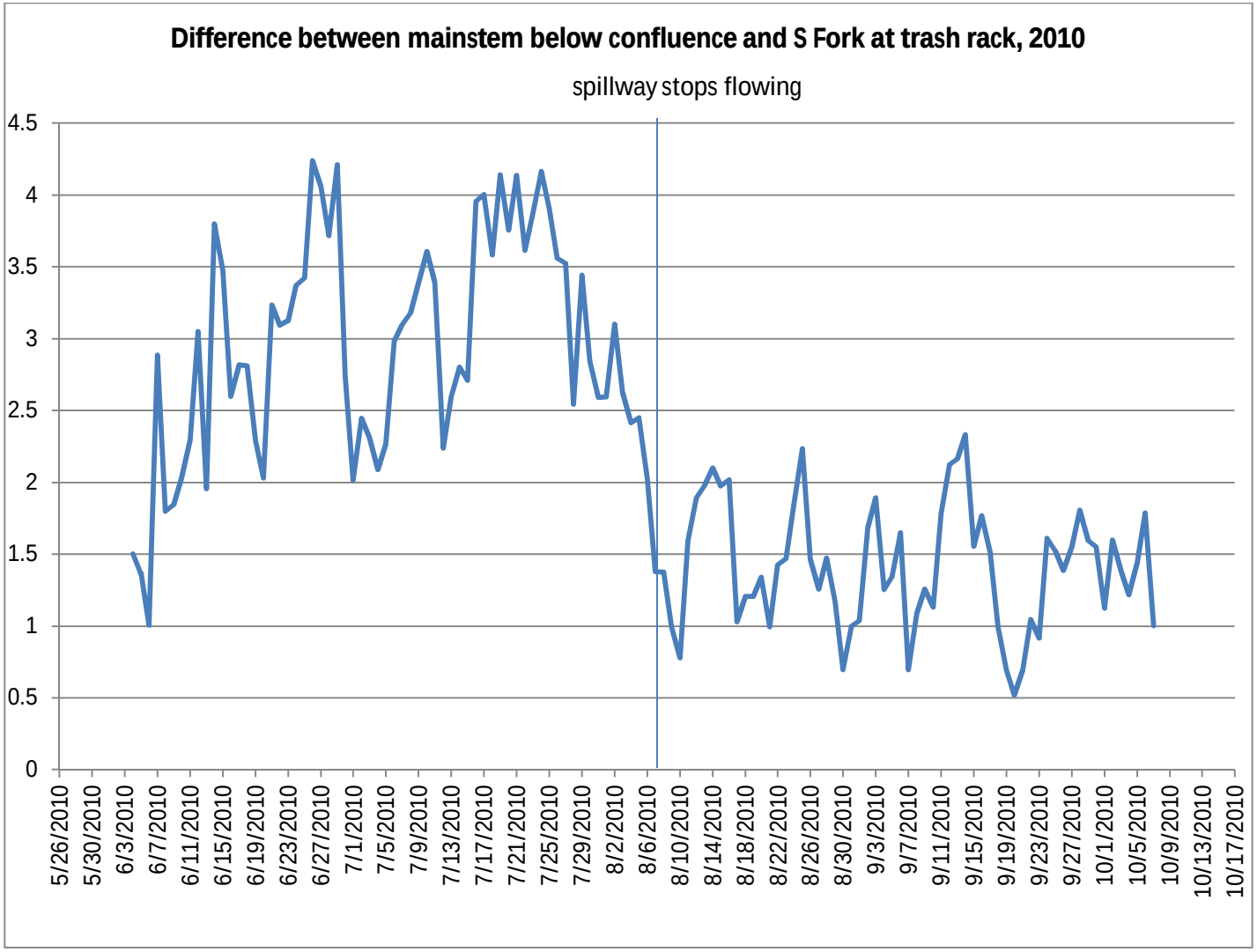

Figure 10. Differences in temperature between the mainstem below the confluence and the South Fork above the intake, 2010.

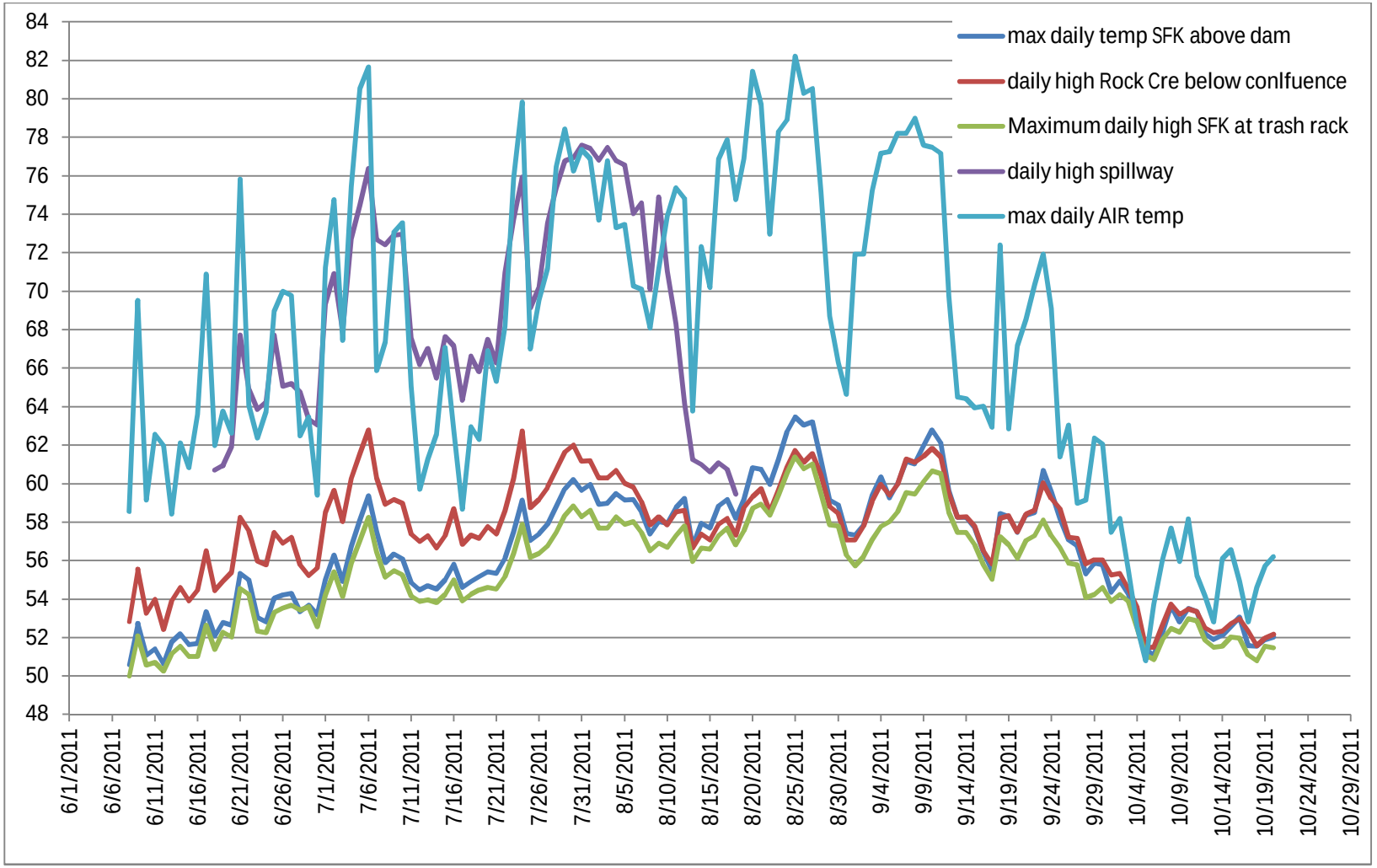

Figure 11. Comparing air temperatures to water temperatures around the North Fork and South Fork Rock Creek confluence. The spillway was dry on August 15, 2011, as represented by the vertical line. The pool below the spillway (purple line) closely follows the air temperature. Prior to August 10, the South Fork site just above the confluence and dam is warmer than the upstream South Fork site, and cooler than the mainstem, as expected. After August 10, the South Fork above the confluence is slightly warmer than the mainstem site.

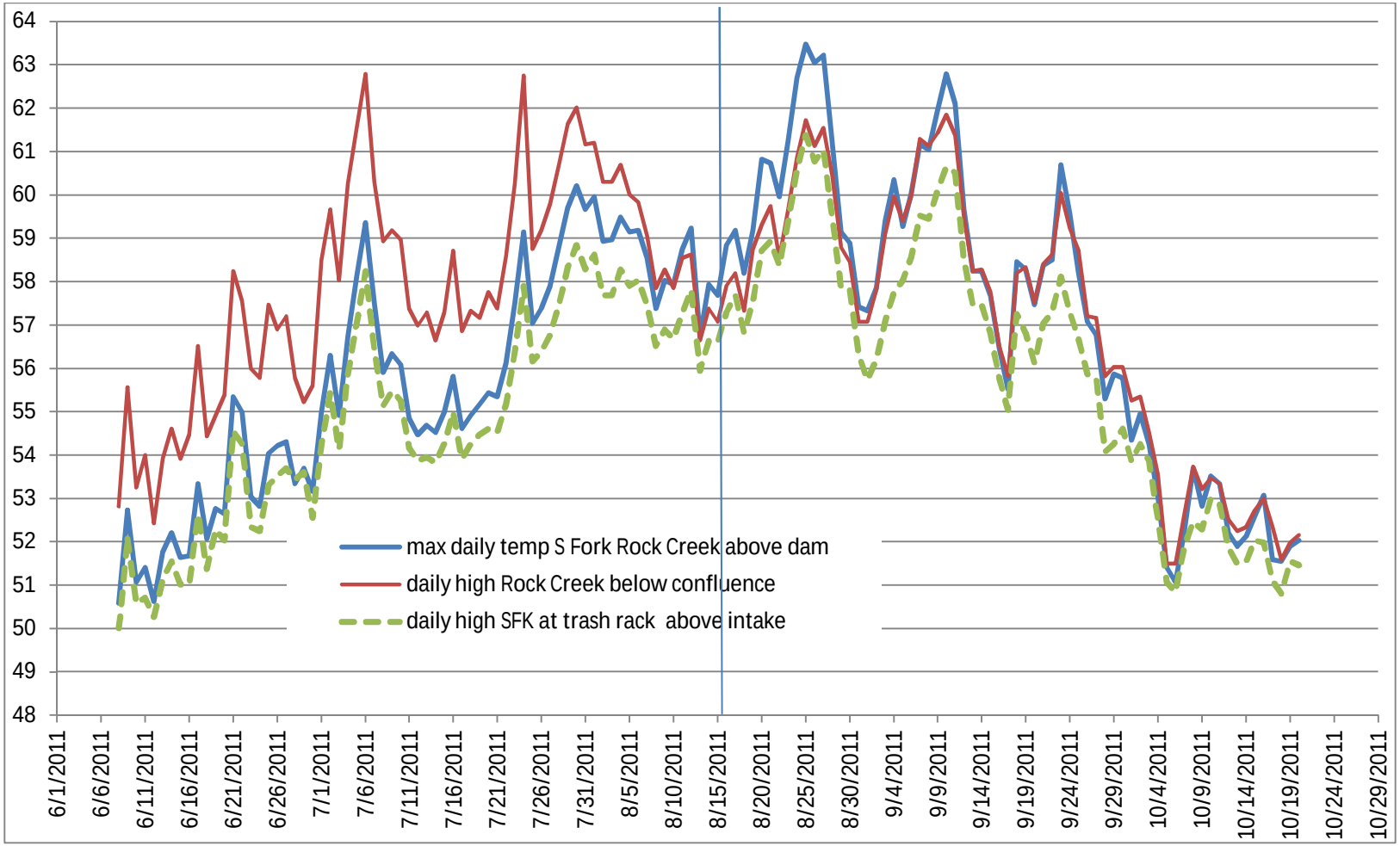

Figure 12. Graph of the three water sites around the confluence of the North and South Fork Rock Creek. See Figure 11 caption for more detailed explanation.

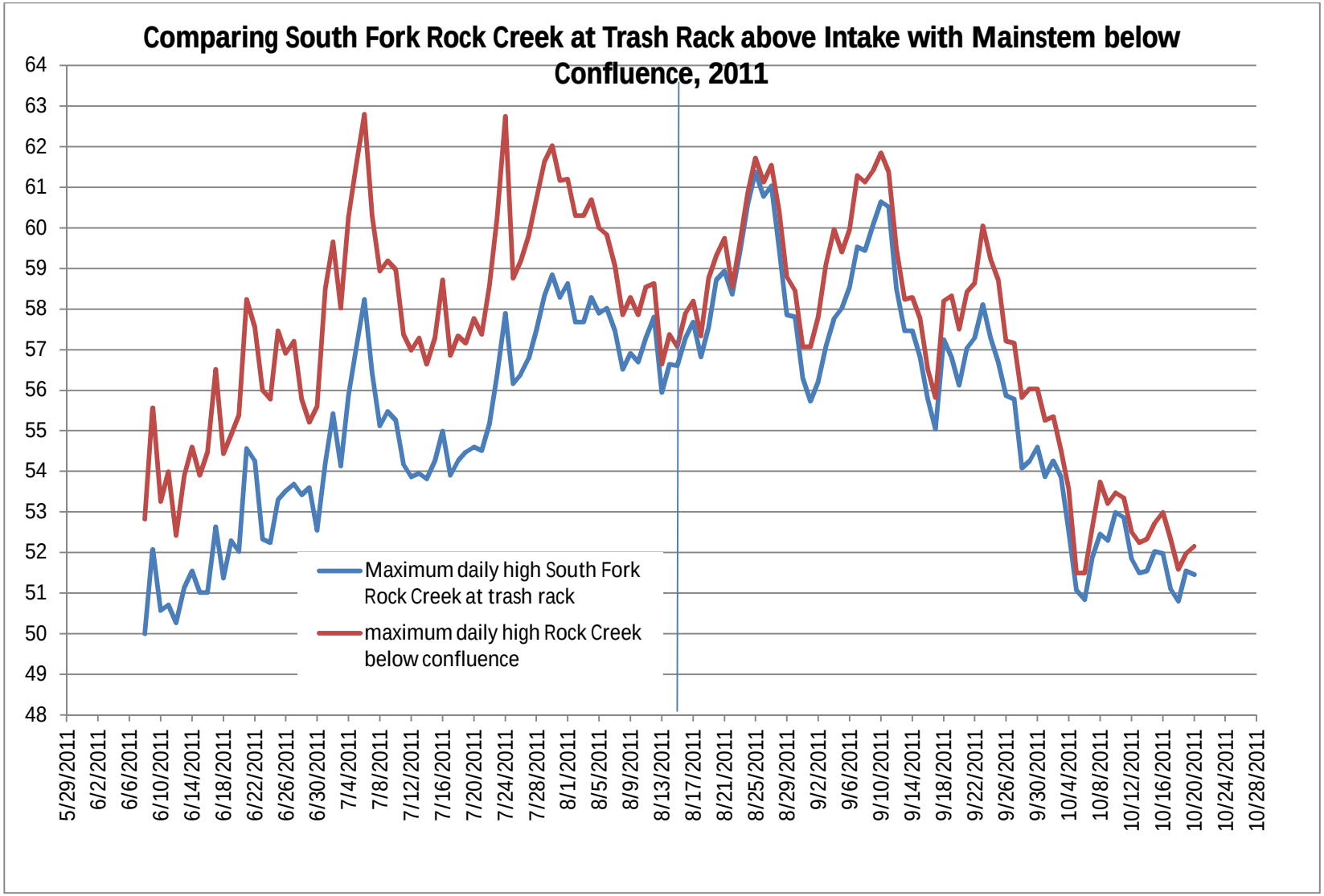

Figure 13. Graph comparing the daily high temperatures at the trash rack in the South Fork Rock Creek above the intake with the mainstem of Rock Creek below the confluence in 2011.

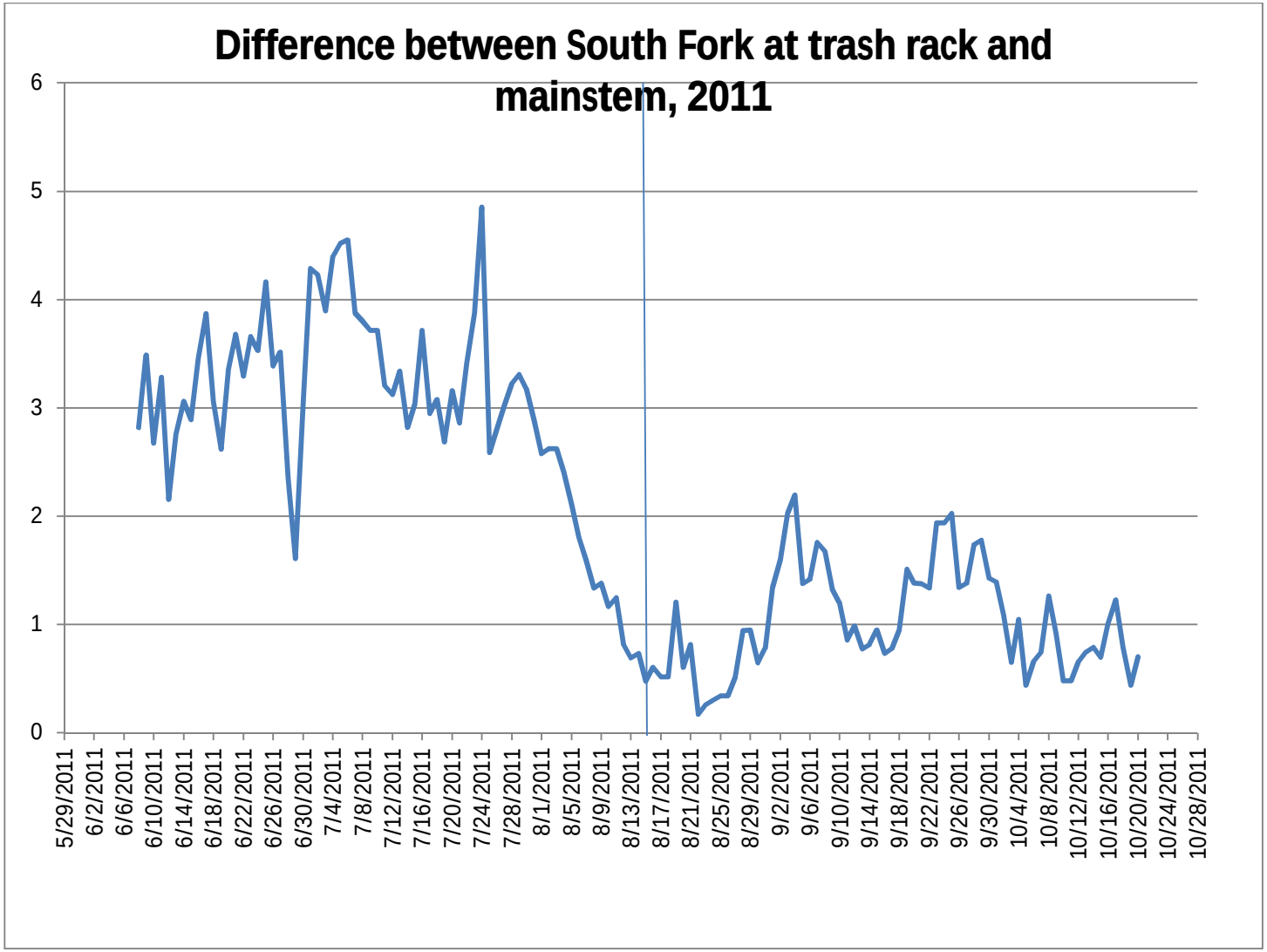

Figure 14. Differences in temperature between the South Fork Rock Creek at the trash rack and the mainstem below the confluence. Note that the differences in temperature decrease starting on July 28, which is two weeks before the reservoir drops below the level of the spillway, and the spillway is dry.

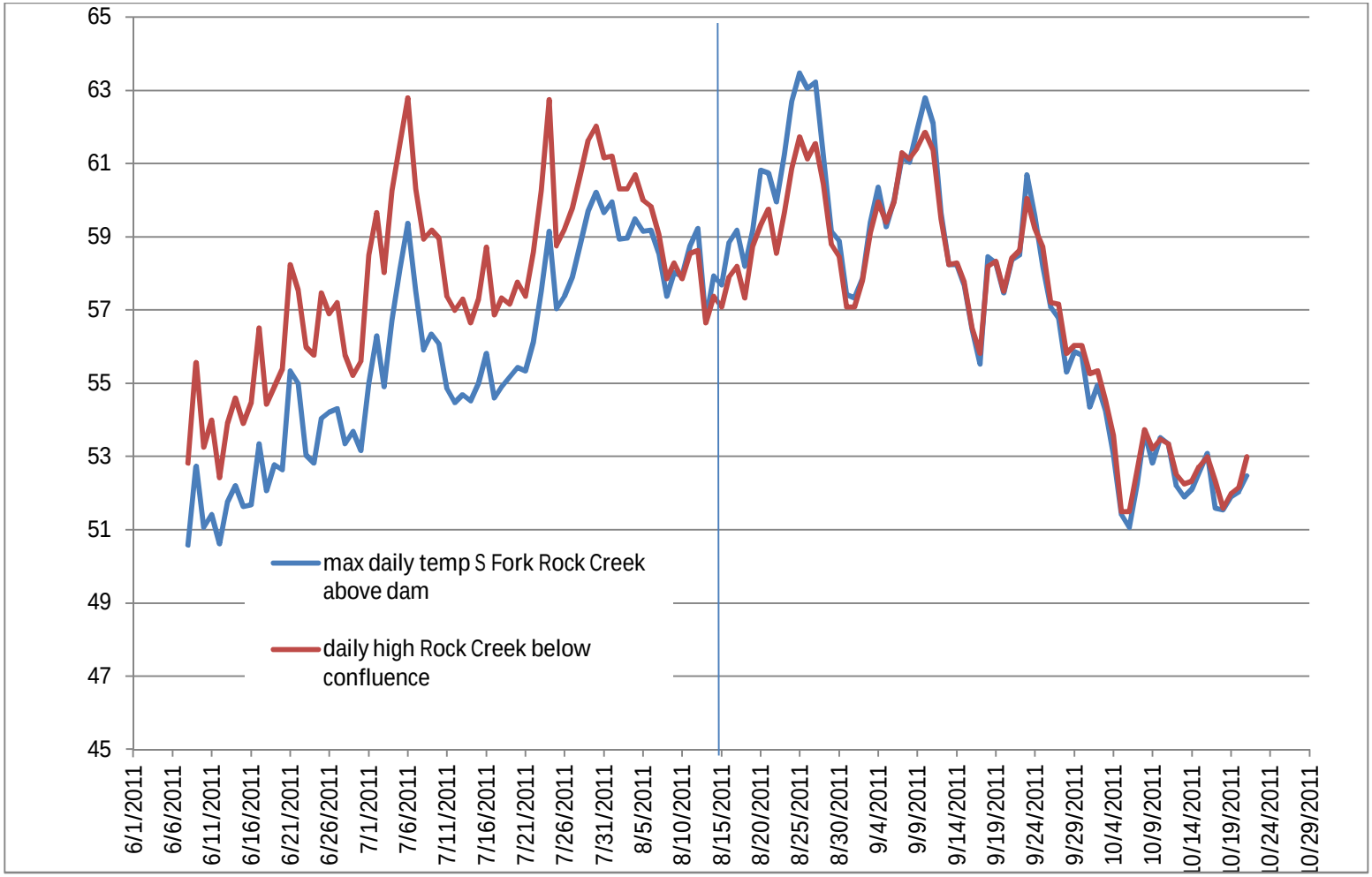

Figure 15. Simplified graph comparing the South Fork site above the reservoir dam and confluence and the mainstem site below the confluence. Note that the mainstem becomes cooler than the South Fork between August 14 and September 10, 2011. The graphs of the two sites show the same peaks and lows, reflecting the influence of air temperatures on both sites.

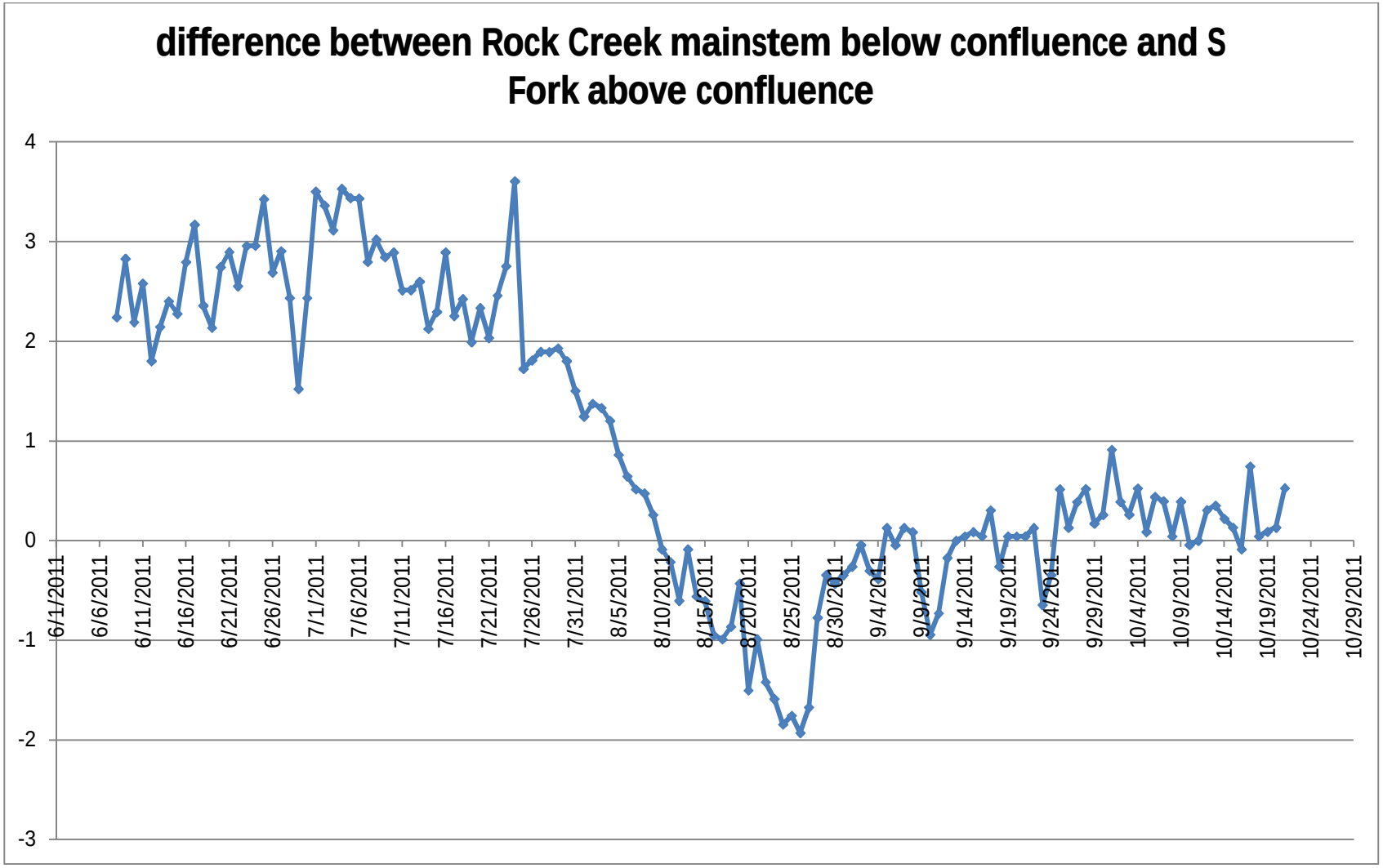

Figure 16. Graph showing the difference in temperature between the Rock Creek mainstem site just below the confluence, and the South Fork Rock Creek site just above the confluence. Note that the difference between the two sites starts to decline starting around July 26. After September 14, they are almost equal, with the mainstem becoming very slightly warmer after September 29.

Table 2: Dates of maximum daily high at three locations.

Date	Maximum daily high South Fork Rock Creek at trash rack	maximum daily temp South ForK Rock Creek above dam	maximum daily high Rock Creek below confluence	difference between above confluence and mainstem
7/6/2011	58.239	59.358	62.791	3.433
7/24/2011	57.893	59.142	62.748	3.6
8/25/2011	61.376	63.475	61.72	-1.755

The date of the warmest temperature for the mainstem Rock Creek site just elow the confluence is relatively early in the season, July 6. A similar peak for this site occurred on July 24. For the two sites on the South Fork Rock Creek above the confluence, the warmest temperatures are on August 25. Other sites in the watershed have their warmest temperature on August 25 also.

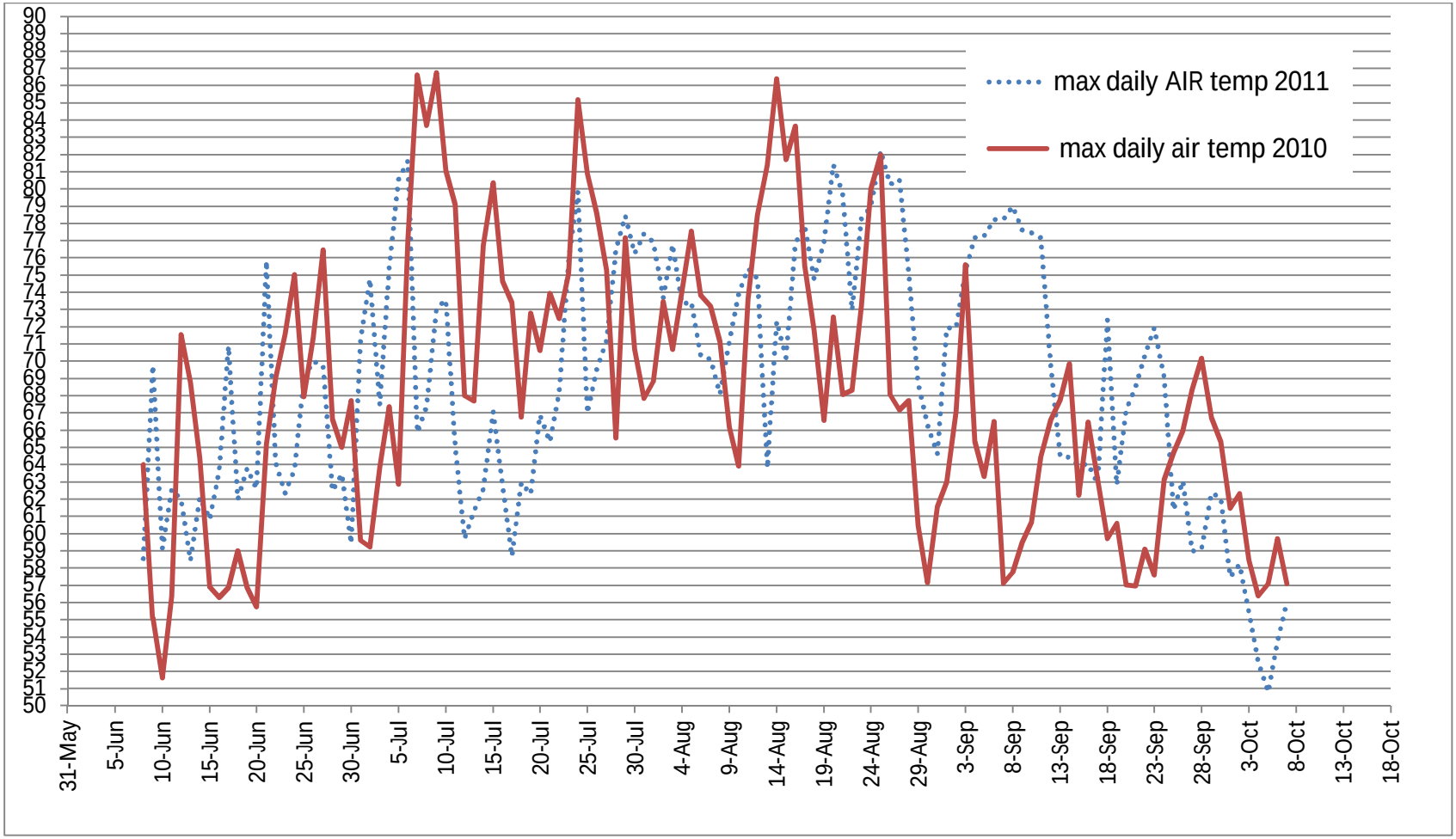

Figure 17. Two years of air temperatures recored near the South Fork Rock Creek intake show the climatic variability from year to year. South Fork Rock Creek air temperatures at intake for 2010 and 2011. Note that 2010 was a warmer year, and the highest peaks occurred between early July and mid-August. In 2011, the sustained peak temperatures occurred in late August and early September.

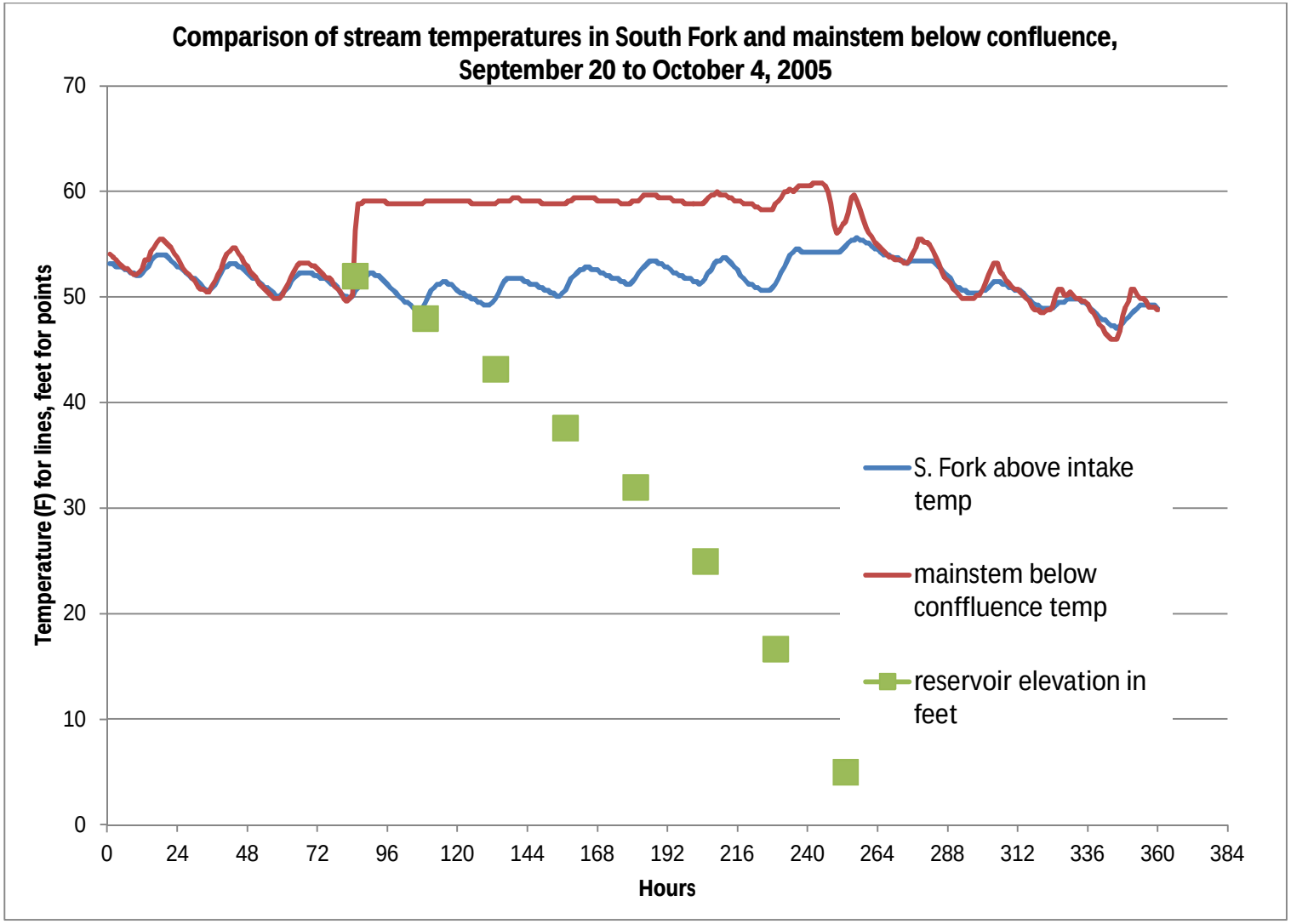

Figure 18. Stream temperatures at the South Fork above the intake compared to the mainstem below the confluence during the drawdown of the reservoir in late September, 2005.

Table 3: Daily Reservoir water surface elevations during the week it took to drain the reservoir, late September 2005.

Date	Reservoir water surface elevation (feet)	Comments
9/23/2005	52.0	Elevation of spillway is 58.0 feet
9/24/2005	48.0	
9/25/2005	43.2	
9/26/2005	37.6	
9/27/2005	32.0	
9/28/2005	25.0	
9/29/2005	16.7	
9/30/2005	5.0	Reservoir empty, streambed flow only.
12/1/2005		Drain valve closed. Begin filling reservoir.
12/9/2005		Reservoir filled to capacity